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Managing Instantly Dense Hot Spot Regions in Wireless Cellular Communication Networks

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ABSTRACT

In a wireless communication cellular network, call activity can be more intensive in some regions than others. These high-traffic regions are called hot spot regions. In typical deployments of wireless cellular networks, traffic hot spots can arise from the non-uniform geographic distribution of the mobile users, and the heavy-tailed nature of their network usage patterns. These hot spots of activity can degrade system performance, by increasing network utilization, wireless interference, call blocking, and even call dropping from failed handoffs for mobile users. In this paper, a hierarchical cellular communication wireless network is characterized by overlapping the service area for managing the new calls users having different mobility speed. The overlapping property of the hierarchical-network provides the advantages that share the traffic load to improve the performance of wireless cellular networks in the highly populated area where both slow speed users and high speed users are available. Picocells are created that are underlaid to two-tier networks for handling the slow or staying speed visitor (outside registered) users. The hierarchical-networks with picocells, microcells and macrocells provide the secondary resource, which provide the services to new calls as well as handoff calls with guard channels by overflow the slow speed visitor users in picocells, slow speed local users in macrocell by sharing the frequency in vertical as well as in horizontal directions. The picocell is installed on four wheeler vehicle may be moved at any place as per necessity and may be utilized to create picocell to handle the load of hot spot area. Such kind of picocell is known as Portable-Picocell (P-Picocell/ P2cell). The call loss probability of new calls is developed through numerical analysis. The proposed schemes are compared with the existing schemes of CAC. Results show that new proposed schemes are more efficient and handle more visitor calls by redirecting calls and sharing of load in P2cell.

Keywords - **guard channel, load redirection, macrocell, microcell, P2cell.**

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1. INTRODUCTION

Demand from wireless users is growing rapidly. In order to provide the efficient, interference-less services against the huge demand of the wireless cellular communication networks, without dropping and blocking calls request is the challenging issue. Beside voice and data services as in 3G, and 4G are expected to provide fully IP-bases services with higher data rates up to 1Gbps for nomadic / slow mobility users and 100 Mbps for high mobility users. Since the existing bandwidth reserved for wireless networks is limited, methods to improve radio spectrum efficiency are needed so that higher network capacity can be achieved.

To release spectrum stress, one way is to design small size cell. Moreover, small cells are not advantageous in the service area where user population is sparse with slow and high speed subscribers. Small cell systems induce an increase handovers by high speed mobile subscribers. Micro-macrocell overlay structures can overcome with these difficulties. . Overlapping property of hierarchical structure provides the advantages that share traffic load to improve the efficiency of call admission control (CAC). It provides the users to access a wireless network service. On the other hand, these are the decision making part of the network carriers that provide services to users with guaranteed quality and achieve maximum possible resource utilization. It is therefore conceivable that CAC policy is one of the critical design considerations in any wireless network. CAC schemes provide the services for both i.e. new as well as old call users.

Subscribers are assigned to picocell, microcell or macrocell based on their mobility speed. A three tier networks as shown in Fig. 1 is proposed in the area where slow speed users and high speed users are scatter with slow speed visitor users, who are temporarily and instantly increased for few days. The size of underlying picocell tier is depends on the area in which visitor users are scatter.

Systems employing multitier cells have been considered in a number of publications. Several methods, for handling new calls and handoff traffic of the defined mobile subscriber speed classes are proposed and performance measures such as the probability of new call blocking, forced termination, and traffic capacity have been determined. In the case of a speed-insensitive selection mechanism, call originations are assigned to a default cell layer which is, in most cases, the lowest

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(microcell) layer [1-2]. It is proposed to direct a new/handoff for the appropriate tier based on its previous speed [3-4]. However, when there is no available channel on the preferred tier, the call will be directed to the other (un-preferred) tier. This is called an overflow. If a speed sensitive selection mechanism is used, arriving calls can be directed to the specific cell layer that depends on the speed class of the mobile station. Many works are also directed in the direction to optimize the performance of the system based on the factors such as roaming speed of users, level of cloudiness of an area, location management, and channel management etc. [5-11].

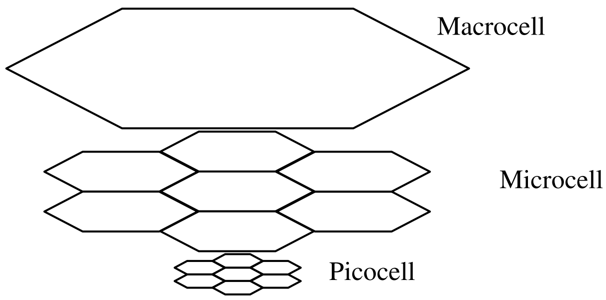

Figure 1: **A proposed three tier cellular communication network**

Two-way overflows are considered in between both tier and a take-back scheme is also proposed in which call is redirect from an un-preferred tier to the preferred tier at the time of handoff take place [12] and a channel rearrangement scheme is proposed by forcing a handset in the overlapping area to take an early handoff permanently [13]. In this paper, a three-tier system is proposed with Guard-Channels in upper two tiers that are reserved to handle the handoff calls only. The aim of this work is to improve the performance of new calls by using overlapping property of the three-tier system that provides the advantage to share the traffic load with frequency sharing techniques in among picocell, microcells and macrocell. By using the overlapping property of three-tier system the load of the cell may be transferred from lower tier to upper tier and vice-versa. Adding capacity in temporary hot spot area is expensive, time consuming by splitting the cells due to installation cost. A picocell makes them a good fit for places needing enhanced capacity [14].

2. PROPOSED STRATEGIES

Let us assume that a macrocell is overlapping with n microcells, and neighbouring to k macrocells. A microcell is overlapping with b picocells or in the area where needed. When a channel request arrives at the macrocell, and if the macrocell has no free channels, then the system force one of the slow calls exist in the macrocell to move into one of the other n overlapping corresponding empty microcells. On the contrary, when a channel request arrives at a microcell, and subscriber is visitor user then it is transferred to picocell, otherwise if the microcell has no free channels, then it can be either overflow to the macrocell, or force one of the slow calls exist in the macrocell to move into one of the other n-1 overlapping empty microcells. Thus, a channel becomes vacant in the macrocell and new call can be overflowed to the overlaid macrocell. It is observed that such frequency sharing provides lot of flexibilities to shift the load among the cells on the hierarchical-tiers in vertical direction in which lowest tier is picocells [15] may be portable installed on four wheeler vehicle. The proposed networks use underlaid Portable-Picocell to microcell that is used proposed scheme **Portable-Picocell Overflow with Vertical Direction Frequency Sharing (P2O-VDFS)**. In this paper we are introducing underlaid picocell(s) to microcell for handling the slow speed visitor subscribers with proposed two-tier model by Vikas Solanki at. el. [16-17] in which **Virtual Direction Frequency Sharing** (VDFS) and **Horizontal Direction Frequency Sharing** (HDFS) schemes are proposed. Proposed two-tier model restricted fast speed users to overflow in microcell and if slow speed users overflowed to un-preferred tier then it will not return automatically, until it forced to overflow for serving the new/handoff calls in macrocell. In this system a fast moving calls do not shift to microcells to avoid more handoff. Thus, overall system can avoid more call dropping probability. The scheme **Horizontal Direction Frequency Sharing** [17] works only in upper-tier with k neighbouring cells, when VDFS scheme fails and not able to provide the service for arriving calls. In [13, 16] some channels are reserved called Guard Channels, that are used only for providing the services to handoff calls. Therefore, guard channels can't be used for serving new call or overflow the new call in un-preferred tier. The VDFS scheme used prior to HDFS scheme to share the frequency in upper most two tiers for handling the traffic load.

The proposed schemes are used underlaid P2cells to handle the hot spot with the two tier system proposed in [17]. P2cell does not have any Guard channels and used allotted frequency only to serve the slow speed new visitor subscribers who are instantly increased for few days in specified area (hot spot).

Table 1 shows the redirection of load in different schemes. Simulation result shows the performance comparison of conventional schemes and proposed schemes. We have seen that proposed schemes perform better.

Table 1: Redirection of load in different schemes

Scheme Reference	Strategy	No. of redirect
12	Overflow+Take Back	1
13	Rearrange+Overflow	k+1
17	VDFS with Guard channels	n
17	HDFS with Guard channels	n+k
Proposed P2O-VDFS	VDFS with picocell	n+1
Proposed P2O-HDFS	HDFS with picocell	n+k+b

2.1 VDFS and HDFS Strategy

Let us consider that there is a channel request arriving at the macrocell M or one of n microcells m_i. If no channel is available in the cell to satisfy that request then proposed VDFS and HDFS strategy will take place, trying to find a channel for serving the said request [16-17]. The VDFS strategy tries to find a channel by shifting calls in the vertical direction, i.e., from one tier to the other tier. When VDFS strategy fails to serve the request, HDFS strategy tries to find a channel by shifting calls in the horizontal direction on the higher tier. Let us consider that some visitor users are instantly increased in small area for few days and therefore network becomes saturated. Here we are proposed a portable picocell underlaid to microcell in the saturated area to handle the visitor subscribers instantly increased for few days. In this paper P2O-VDFS (Portable Picocell Overflow-VDFS) and P2O-HDFS (Portable Picocell Overflow-HDFS) strategies are proposed to improve the performance of the network in area, where some visitor users are increased instantly for few days. Simulation results shows that the proposed strategies improve the efficiency of wireless cellular networks even visitor slow subscribers are increased instantly in an underlaid picocell area. In the following sub-sections, we discuss overflow and channel sharing in vertical as well as horizontal direction for slow subscribers. The sub-sections describe the P2O-VDFS and P2O-HDFS strategies for slow subscribers only, and model uses same strategy for fast subscribers as discussed in [17].

2.2 Proposed P2O-VDFS Scheme

In P2O-VDFS strategy, the system transfers the calls among the three-tiers. The tiers may be either homogeneous or heterogeneous. In this work, tiers are considered as homogeneous. In the following, we limit the discussion into slow calls only. When there is a channel request arriving to microcell m_i, $1 \leq i \leq n$, the operation is showing by the flowchart 'A' (Fig. 2).

The new slow subscriber arrival request is handling as per algorithm shown by the flowchart 'A' in Fig. 2. Therefore as per flowchart 'A' the operation 2 (Op. 2) is applied if the slow user is visitor subscriber and channel is available otherwise Op.3 is take place. On the other hand if microcell m_i is full and subscriber is home slow user then it will be overflowed to macrocell M to serve the request (Op. 5). But the macrocell M is also full, therefore the frequency sharing in vertical direction takes place and tries to pick the slow subscriber, which is currently served in macrocell M and then said subscriber can be handoff to corresponding microcell with a free channel (Op. 6 & Op. 7).

When P2O-VDFS fails to serve the request for slow visitor subscriber, then V2O-HDFS scheme tries to find the channel by shifting calls in the horizontal direction for serving the said request as per HDFS scheme in [17].

2.3 Proposed P2O-HDFS Scheme

In this strategy, the calls are transferred horizontally in underlaid picocell tier. If previous strategy P2O-VDFS fails then P2O-HDFS take place. This strategy takes place by forcing the subscriber on picocell p_l, $2 \leq l \leq b$ to early handoff in neighbouring cell as shown in flowchart 'B' (Fig. 3).

Suppose new visitor subscribers SV_1 and SV_2 arrive at microcell m4 (See Fig. 4). As per proposed algorithm, visitor call request should be overflowed to corresponding picocell. SV_1 subscriber overflow to P2 picocell and SV_2 subscriber try to overflow to P1 picocell which already runs out off channel therefore P2O-VDFS scheme fails in providing the service to SV_2 subscriber. In such situation P2O-HDFS scheme is applied in picocell to provide the service. PV_1 is only possible candidate who can take early handoff to P3 picocell. Subscriber SV_1 perform operation Op.2 to get service from the network, but subscriber SV_2 can't get connection by operation Op.2 as per flowchart 'A'. It requires P2O-HDFS sequence of operations Op.9, Op.10 and Op.11 of flowchart 'B' to get connection from the network.

3. MODEL DESCRIPTION

The arrival rates of new calls and handoff calls for both low and high speed users are assumed to be Poisson processes. The Poisson distribution is a suitable approach to represent handoff calls [18]. **The cell dwelling time (CDT)** is the time a mobile user spends in a cell before it is handed off to another cell. It depends on the speed of the mobile user and the size of the cell. The cell dwelling time [12] can be calculated as follows:

$$\frac{1}{\mu_d} = \frac{\Pi r}{2V}$$

Where V is the velocity of subscriber and r is the radius of the cell.

Note: Subscript v, s and f are indicating slow visitor, slow and fast user respectively while superscript p, m and M represent picocell, microcell and macrocell respectively.

The inverse of the cell dwell time is the **cell cross-over rate (CCOR)** and therefore, for fast and slow subscriber in macrocell, slow and slow visitor (later call only visitor) subscribers in microcell and picocell are μ_{df}^{M} , μ_{ds}^{M} , μ_{ds}^{m} **and** μ_{dv}^{p} respectively as follows:

$$\mu_{df}^{M} = \frac{2V_f}{\pi r_n} \quad ; \quad \mu_{ds}^{M} = \frac{2V_s}{\pi r_n}$$

$$\mu_{ds}^{m} = \frac{2V_s}{\pi r_n} \quad ; \quad \mu_{dv}^{p} = \frac{2V_v}{\pi q_n}$$

The handoff probabilities [19] for fast and slow subscribers in a macrocell are:

$$P_{hf}^{M} = \frac{\mu_{df}^{M}}{\mu_e + \mu_{df}^{M}}$$

$$P_{hs}^{M} = \frac{\mu_{ds}^{M}}{\mu_e + \mu_{ds}^{M}}$$

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Similarly the handoff probability for slow subscriber in microcell may be calculated as

$$P_{hs}^{m} = \frac{\mu_{ds}^{m}}{\mu_e+\mu_{ds}^{m}}$$

and the handoff probability for visitor subscriber in picocell may be calculated as

$$P_{hv}^{p} = \frac{\mu_{dv}^{p}}{\mu_e + \mu_{dv}^{p}}$$

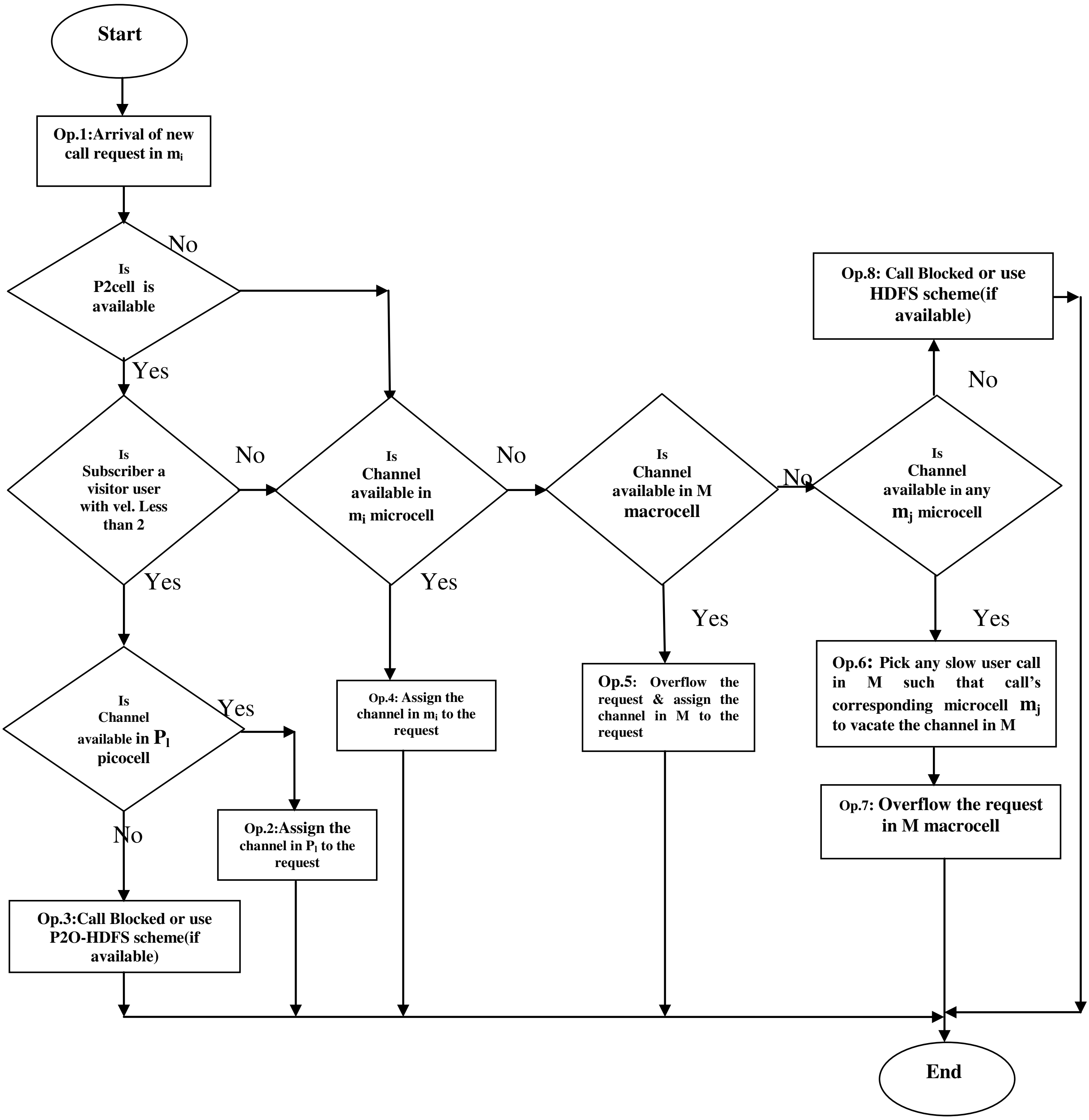

Figure 2: Flowchart 'A' showing Operations occurred on Call request by slow subscribers arrived to microcell

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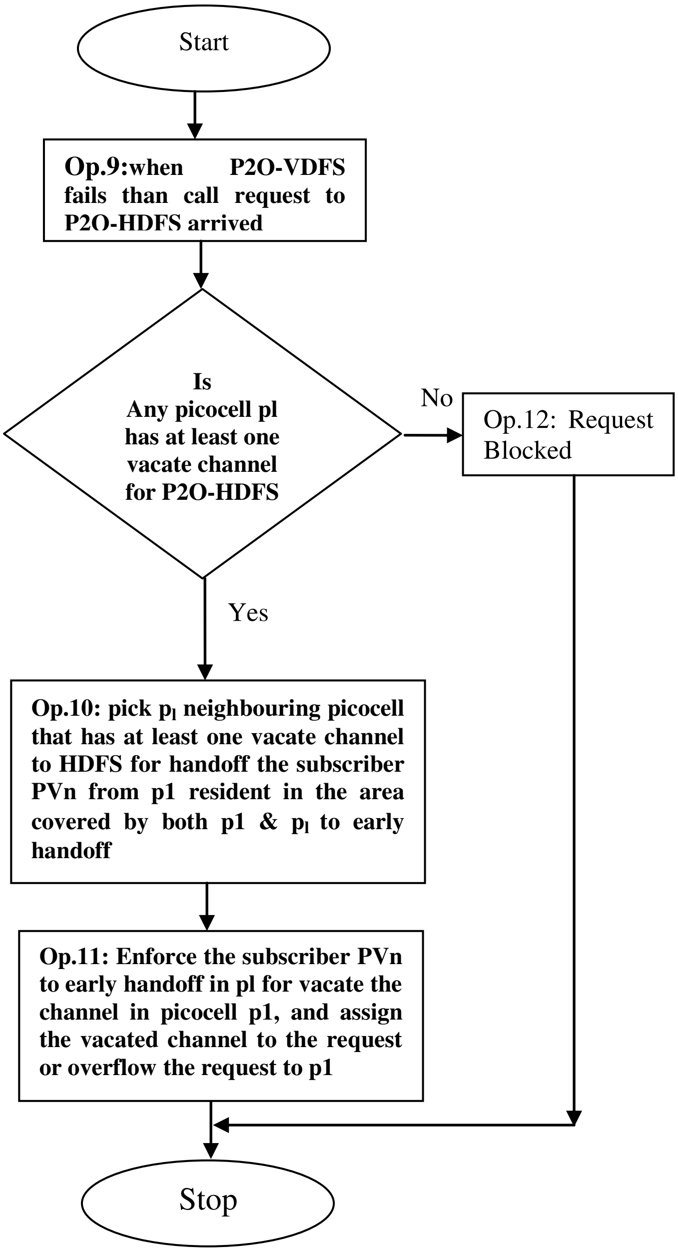

Figure 3: Flowchart 'B' showing Operations occurred on Call request to HDFS

Where μ_e is the inverse of the mean unencumbered call duration time. The ***unencumbered call duration (UCD)*** of a call is the amount of time that the call may remain in progress if it can continue to complete without being dropped, and it also follows a negative exponential distribution. The mean **channel occupancy time (COT) / session duration** is the mean of minimum of unencumbered call duration and cell dwell time [19], which should be

$$1/\mu_{ef}^{M} = \frac{1}{\mu_e+\mu_{df}^{M}} \quad ; \quad 1/\mu_{es}^{M} = \frac{1}{\mu_e+\mu_{ds}^{M}}$$

$$1/\mu_{es}^{m} = \frac{1}{\mu_e+\mu_{ds}^{m}} \quad ; \quad 1/\mu_{ev}^{p} = \frac{1}{\mu_e+\mu_{dv}^{p}}$$

For fast, slow in macrocell and slow, visitor subscribers in microcell and picocell respectively.

Some more traffic parameters that are used in performance analysis of P2O-VDFS and P2O-HDFS are as follows:

A. For macrocell

Description	fast users	slow users
1. Traffic rate of new calls	λ_{nf}^{M}	-
2. Traffic rate of handoff calls	λ_{hf}^{M}	λ_{hs}^{M}
3. Traffic rate of overflow calls	-	λ_{os}^{M}
4. Traffic rate of vertical direction call	-	λ_{vs}^{M}
5. Traffic rate of horizontal direction calls	λ_{zf}^{M}	λ_{zs}^{M}
6. Aggregate traffic rate	λ_{tf}^{M}	λ_{ts}^{M}

B. For microcell

Description	visitor users	slow users
1. Traffic rate of new calls	-	λ_{ns}^{m}
2. Traffic rate of handoff calls	-	λ_{hs}^{m}
3. Traffic rate of overflow calls	-	-
4. Traffic rate of vertical direction calls	-	λ_{vs}^{M}
5. Traffic rate of horizontal direction calls	-	-
6. Aggregate traffic rate	-	λ_{ts}^{m}

C. For picocell

Description	visitor users	slow users
1. Traffic rate of new calls	λ_{nv}^{m}	-
2. Traffic rate of handoff calls	λ_{hv}^{p}	-
3. Traffic rate of overflow calls	-	-
4. Traffic rate of vertical direction calls	-	-
5. Traffic rate of horizontal direction calls	λ_{zv}^{p}	-
6. Aggregate traffic rate	λ_{tv}^{p}	-

4. PERFORMANCE MEASUREMENT AND ANALYSIS

In this section, the proposed model described above will be analysed to slow subscribers. The traffic flows include new, handoff calls, and those incurred by vertical and vertical-horizontal direction frequency sharing. These traffic flows are all assumed to follow the Poisson's process. It is assumed that C_T and C_R are the total number of available channels and guard channels for handoff calls in each cell respectively. Therefore, vacant number of channels to handle the new calls are C_A=C_T-C_R. If the free channels in a cell are greater than C_R then there will be no problem to handle handoff as well as call set up of new

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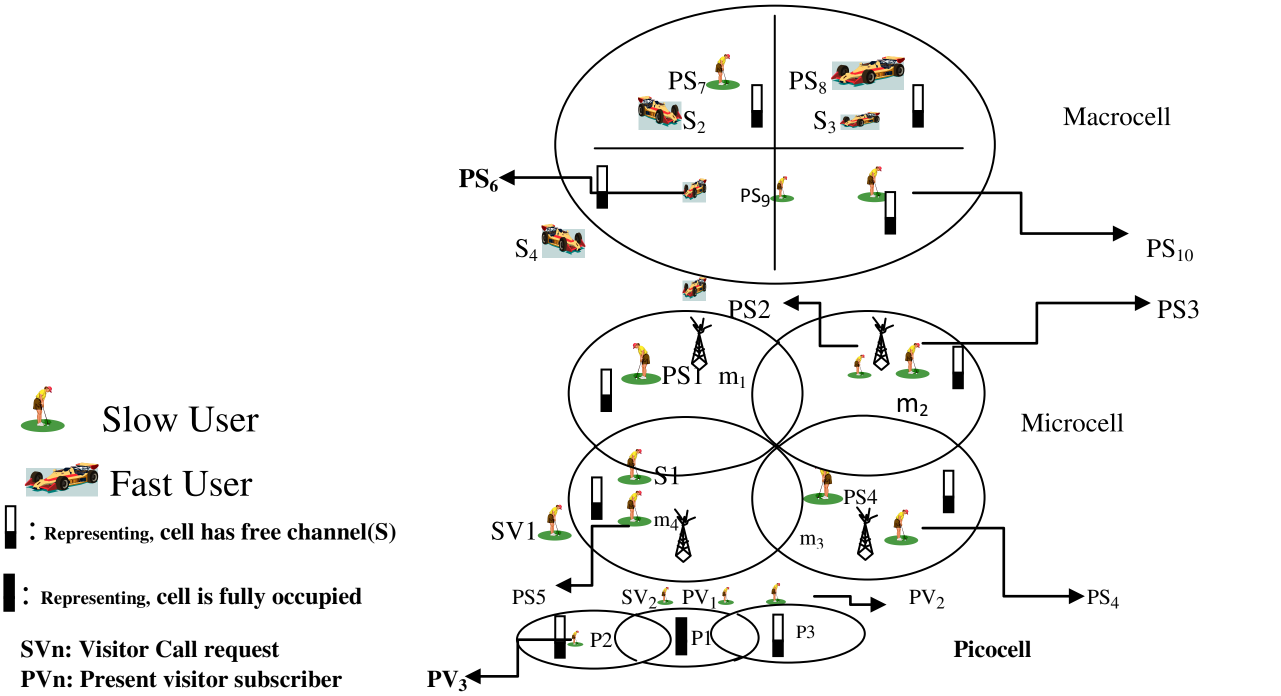

SVn: Visitor Call request
PVn: Present visitor subscriber
Sn: Call request
PSn: Present subscriber

Figure 4: Channel sharing in the horizontal direction for visitor slow subscribers

calls. But, if any cell has less or equal number of channels than C_R, a free channel performing only handoff and though new calls, or overflow the slow speed users/forced handoff in upper/lower tier are handled by proposed P2O-VDFS and/or P2O-HDFS schemes for better CAC to improve the performance of cellular networks.

4.1 Performance of Proposed P2O-VDFS Scheme

The target is to give the efficient scheme for handling the slow speed new calls in the area, where some visitors are increased instantly for few days, so that system will reduce the call lose probability of slow speed new calls. Therefore, the ***calls lose probabilities*** P_{ls} and P_{lv} of new calls for slow and visitor subscribers respectively are derived. These are the probability for a channel request being refused after the P2O-VDFS.

Therefore call loss probabilities are:

$$P_{ls} = P_b^m P_b^M P_{vs}$$

$$P_{lv} = P_b^p$$

Where P_{vs} is the failure probability of sharing the vertical direction

$$P_{vs} = 1 - P_{sv}(1 - P_b^m) \quad (1)$$

Where $(1 - P_b^m)$ is the probability of microcell has at least one free channel and P_{sv} is the probability having a slow subscriber that is currently served by the macrocell and also covered by the microcell to be served them.

$$P_{sv} = 1 - \left(\frac{n-1}{n}\right)^{C_A^M} (1 - P_s) \quad (2)$$

Where $\left(\frac{n-1}{n}\right)^{C_A^M} (1 - P_s)$ represents the probability of all slow subscriber serving in macrocell are not located in this particular microcell and P_s is the probability of slow subscribers located in the macrocell for the same area.

The P_b^M, P_b^m and P_b^p are the probabilities that a mobile subscriber has no free channel in a macrocell and microcell and picocell respectively.

$$P_b^M = \frac{\dfrac{\left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right)^{C_A^M}}{C_A^M!}}{\sum_{l=0}^{C_A^M} \dfrac{\left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right)^{l}}{l!}} \quad (3)$$

$$P_b^m = \frac{\frac{(\frac{\lambda_{ts}^m}{\mu_{es}^m})^{C_A^m}}{C_A^m!}}{\sum_{l=0}^{C_A^m}\frac{(\frac{\lambda_{ts}^m}{\mu_{es}^m})^l}{l!}} \quad (4)$$

$$P_b^p = \frac{\frac{(\frac{\lambda_{tv}^p}{\mu_{ev}^p})^{C_A^p}}{C_A^p!}}{\sum_{l=0}^{C_A^p}\frac{(\frac{\lambda_{tv}^p}{\mu_{ev}^p})^l}{l!}} \quad (5)$$

Here $(\frac{\lambda_{tf}^M}{\mu_{ef}^M}+\frac{\lambda_{ts}^M}{\mu_{es}^M})$, $(\frac{\lambda_{ts}^m}{\mu_{es}^m})$ and $(\frac{\lambda_{tv}^p}{\mu_{ev}^p})$ are the traffics contributed by the subscribers on macrocell, microcell and picocell respectively for available channels.

Let variables λ_{tf}^M, λ_{ts}^M, λ_{ts}^m and λ_{tv}^p denotes the arrival rates and μ_{ef}^M, μ_{es}^M, μ_{es}^m, and μ_{ev}^p, denotes the service rates.

Next, it is need to calculate the aggregate traffic λ_{tf}^M, λ_{ts}^M, λ_{ts}^m and λ_{tv}^p by analysis model [20]. These traffics are composed of new calls, handoff calls, overflow calls, and channel sharing calls. Variable λ_{tf}^M is aggregate traffic rate incurred by new calls and handoff calls into macrocell by the fast subscribers:

$$\lambda_{tf}^M = \lambda_{nf}^M + \lambda_{hf}^M$$

Where

$$\lambda_{hf}^M = \lambda_{tf}^M(1-P_b^M)P_{hf}^M$$

Here λ_{hf}^M means the handoff rate, is the aggregate traffic rate itself successfully stays in the macrocell $\lambda_{tf}^M(1-P_b^M)$ times with the handoff probability P_{hf}^M. Similarly, λ_{ts}^M is the aggregate traffic rate incurred by overflow calls and handoff calls into a macrocell by slow mobile subscribers.

$$\lambda_{ts}^M = \lambda_{os}^M + \lambda_{hs}^M$$

Where

$$\lambda_{os}^M = n\lambda_{ts}^m P_b^m$$

Here λ_{os}^M means the overflow rate incurred by overflow from the n microcells covered by the macrocell and λ_{hs}^M is the handoff calls into a macrocell by slow mobile subscribers, which equals the slow subscribers successfully staying on the high tier $\lambda_{ts}^M(1-P_b^M)$ times the handoff probability P_{hs}^M, that is

$$\lambda_{hs}^M = \lambda_{ts}^M(1-P_b^M)\,P_{hs}^M$$

The traffic rate of λ_{ts}^m is incurred by new calls, handoff calls, and calls caused by channel-sharing for slow subscribers:

$$\lambda_{ts}^m = \lambda_{ns}^m + \lambda_{hs}^m + \lambda_{vs}^m$$

Where λ_{hs}^m is the handoff calls equals the slow subscriber successfully handoff on lower tier

$$\lambda_{hs}^m = \lambda_{ts}^m(1-P_b^m)P_{hs}^m$$

and $\lambda_{vs}^m$is caused by vertical direction frequency sharing strategy,

$$\lambda_{vs}^m = \frac{\lambda_{vs}^M}{n}\left(\frac{\lambda_{ts}^M}{\lambda_{ts}^M+\lambda_{tf}^M}\right)P_{cvs}$$

Here λ_{vs}^M is the load caused by the vertical direction frequency sharing by slow subscriber in the physical area covered by a macrocell (including one macrocell and n microcell) and P_{cvs} times is the probability that a subscriber in macrocell can be rearranged to a microcell but only a fraction 1/n of the load will be injected to the microcell. The rate λ_{vs}^M can be derived as follows:

$$\lambda_{vs}^M = n(\lambda_{ns}^m + \lambda_{hs}^m)P_b^m P_b^M,$$

It equals the new call arrival rate and handoff call rate of slow subscribers into the n microcells $n(\lambda_{ns}^m + \lambda_{hs}^m)$, P_b^m is times probability that they see no free channel in the local microcell, and P_b^M times probability that they see no free channel in the macrocell.

Finally the term $(\frac{\lambda_{ts}^M}{\lambda_{ts}^M+\lambda_{tf}^M})$ is the ratio of vertical direction frequency sharing flows by slow subscribers into microcells.

The traffic rate of λ_{tv}^p is incurred by new calls, and handoff calls for visitor subscribers:

$$\lambda_{tv}^p = \lambda_{nv}^p + \lambda_{hv}^p$$

Where λ_{hv}^p is the handoff calls equals the visitor subscribers successfully handoff on lower tier

$$\lambda_{hv}^p = \lambda_{tv}^p(1-P_b^p)P_{hv}^p$$

4.2 Performance of Proposed P2O-HDFS Scheme

In this section, analysis is made of the proposed P2O-HDFS scheme. If some visitor mobile subscribers are increased instantly for few days in a particular place then microcell may be exhausted and therefore proposed scheme VDFS in [16-17] may be helpless in handling the load with QoS. If a visitor mobile subscriber call request found no free channel in its local cell then previously discussed scheme P2O-VDFS fail to perform, and P2O-HDFS scheme take place. The goal is to drive the ***calls lose probabilities*** P_{ls} and P_{lv} of new calls for slow and visitor subscribers respectively.

The call loss probabilities are:

$$P_{ls} = P_b^m P_b^M P_{vs} P_z$$

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$$P_{lv} = P_b^p P_z^p$$

Where probability P_{vs} is the failure probability of vertical direction sharing as given in (1), and P_z, P_z^p are the failure probabilities of horizontal direction sharing in Macrocell and Picocell respectively is as follows:

$$P_z = 1 - P_{est}^M((1 - P_b^M)(1 - P_{vs}'))$$

$$P_z^p = 1 - P_{est}^p\left(1 - P_b^p\right)$$

Where P_{vs}' is the failure probability of vertical direction sharing for macrocell M_i as given in (1), and P_{est}^M, P_{est}^p are the probabilities for staying at least one subscriber in early handoff area in macrocell and picocell respectively given as:

$$P_{est}^M = 1 - (\frac{(R_e)^2}{(R_n)^2})^{C_A^M}$$

$$P_{est}^p = 1 - (\frac{(q_e)^2}{(q_n)^2})^{C_A^p}$$

P_b^M, P_b^m, and P_b^p can be derived as (3), (4) and (5) respectively, but their values are different for different aggregate traffic rates. The horizontal direction sharing affects only traffic flows on macrocell, and picocell therefore λ_{ts}^m in microcell are same as that in the vertical direction frequency sharing as discussed in section 4.1, but their values are dependent on P_b^M, and P_b^m in macrocell and P_b^p in picocell when derived as for horizontal direction sharing.

In macrocell, the aggregate rate λ_{tf}^M incurred by new calls, handoff calls, and horizontal direction sharing calls for fast subscriber:

$$\lambda_{tf}^M = \lambda_{nf}^M + \lambda_{hf}^M + \lambda_{zf}^M$$

λ_{zf}^M caused by horizontal direction sharing can be calculated as:

$$\lambda_{zf}^M = \left(\lambda_{nf}^M + \lambda_{hf}^M\right) P_b^M P_{vs} P_{est}^M$$

It equals the new call arrival rate and handoff rate into macrocell($\lambda_{nf}^M + \lambda_{hf}^M$), times probability that they found no free channel in the macrocell P_b^M, times probability that they fail in vertical direction sharing P_{vs}, and times probability that at least one subscriber staying in early handoff area P_{est}^M. Similarly λ_{ts}^M is the aggregate traffic rate incurred by overflow calls, handoff calls, and horizontal direction sharing in macrocell by slow subscribers:

$$\lambda_{ts}^M = \lambda_{os}^M + \lambda_{hs}^M + \lambda_{zs}^M$$

Where λ_{zs}^M is horizontal direction sharing by slow subscriber,

$$\lambda_{zs}^M = n(\lambda_{ns}^m + \lambda_{hs}^m) P_b^m P_b^M P_{vs} P_{est}^M$$

which equals the new call arrival rate and handoff rate of slow subscribers into the n microcells $n(\lambda_{ns}^m + \lambda_{hs}^m)$, times the probabilities that they found no free channel in the local microcell P_b^m, and neither in the macrocell P_b^M, times the probability that they fail in vertical direction sharing P_{vs}, and times probability that at least one subscriber staying in early handoff area P_{est}^M.

In picocell, the aggregate rate λ_{tv}^p incurred by new calls, handoff calls, and horizontal direction sharing calls for visitor subscriber:

$$\lambda_{tv}^p = \lambda_{nv}^p + \lambda_{hv}^p + \lambda_{zv}^p$$

λ_{zv}^p caused by horizontal direction sharing can be calculated as:

$$\lambda_{zv}^p = \left(\lambda_{nv}^p + \lambda_{hv}^p\right) P_b^p P_{est}^p$$

It equals the new call arrival rate and handoff rate into picocell($\lambda_{nv}^p + \lambda_{hv}^p$), times probability that they found no free channel in the picocell P_b^p, and times probability that at least one subscriber staying in early handoff area P_{est}^p.

5. NUMERICAL EXAMPLES AND DISCUSSION

We consider 6 cases denoted from (a) to (f) for comparison as follows:

a) The call loses probabilities of **Take Back (TB)** scheme in reference [12] for slow subscribers are denoted by $\boldsymbol{P_b^m\, P_b^M}$.
b) The call loses probabilities of **Channel Rearrangement (CR)** scheme in reference [13] for slow subscribers are denoted by $\boldsymbol{P_b^m P_r P_b^M}$.
c) The call loses probabilities of **Vertical Direction Frequency Sharing (VDFS)** scheme in reference [17] for slow subscribers are denoted by $\boldsymbol{P_b^m P_b^M P_{vs}}$.
d) The call loses probabilities of **Horizontal Direction Frequency Sharing (HDFS)** scheme in reference [17] for slow subscribers are denoted by $\boldsymbol{P_b^m P_b^M P_{vs} P_z}$.
e) The call loses probabilities of **P2O-Vertical Direction Frequency Sharing (P2O-VDFS)** scheme for slow subscribers are denoted by $\boldsymbol{P_b^m P_b^M P_{vs} P_b^p}$ or ($P_{ls}.P_{lv}$).
f) The call loses probabilities of **P2O-Horizontal Direction Frequency Sharing (P2O-HDFS)** scheme for slow subscribers are denoted by $\boldsymbol{P_b^m P_b^M P_{vs} P_z\, P_b^p P_z^p}$ or ($P_{ls}.P_{lv}$).

It is assumed that the total traffic to the entire area follows the Poisson process with the rate λ and the fraction $q + q'$ of this traffic from slow mobile subscribers (q for slow and q' for visitor subscribers). In [17], the performance of VDFS and HDFS had been calculated for Pvs = 0.500095(assumed), but in this paper we are calculating the performance of VDFS, HDFS and proposed schemes using the (1).

To compare the different strategies listed (a) to (f), we assumed some parameters as shown in Table 2.

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Table 2: List of parameters taken for performance comparison

S.No	Parameter name	Value		
		Macrocell	Microcell	Picocell
1	**Radius**	800 m	400 m	250 m
2	**Average velocity**	40 km/hr	4km/hr	1km/hr
3	**The call arrival rate of slow subscriber**	qλ	qλ/n	$q'\lambda$/nb
4	**The call arrival rate of fast subscriber**	$(1-q-q')\lambda$	0	0
5	**Number of channels**	37	9	7
6	**Guard channels**	8	2	0

Here q and q' are tune the amount of slow and slow visitor subscribers respectively in an area. n and b takes care of size difference between macrocell and microcell and microcell and picocell respectively. Here assume that n=4, b=4, q=0.5, q'=0.2and the mean holding time for a call is 140 seconds.

Table 3: Number of assumed channels in the different schemes to be compared

S.No	Scheme	Guard Channels (picocell, microcell, macrocell)	Available number of channels- C_A for new calls		
			Picocell	Microcell	Macrocell
1	TB scheme	Φ,0,0	Φ	9	37
2	CR scheme	Φ,0,0	Φ	9	37
3	VDFS	Φ,2,8	Φ	7	29
4	HDFS	Φ,2,8	Φ	7	29
5	P2O-VDFS	0,2,8	7	7	29
6	P2O-HDFS	0,2,8	7	7	29

To different schemes as mentioned above from (a) to (f), the call loss probability is calculated and compared in Fig. 5 and Fig. 6 for slow subscribers. It is assumed that for fast and slow subscribers, the available number of channels in the cell is as shown in Table 3. Because first four schemes in the Table 3 have not any picocell, therefore number of channels and guard channels are represented by Φ.

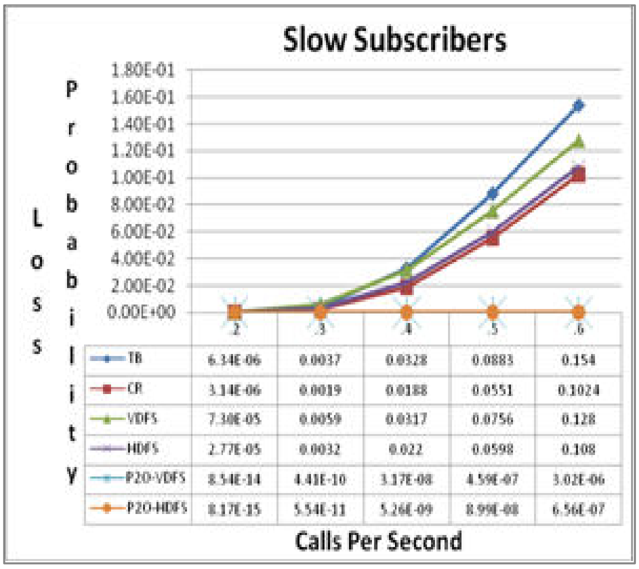

Figure 5(a): Comparison of numerical analysis on call loss probability with (.2 to.6) call arrival rate for slow subscribers

It is found that CR scheme perform better than TB for slow subscribers, as it has channel rearrangement strategy with overflow scheme, that has more redirecting choices as compare to TB (see Fig. 5). The VDFS and HDFS schemes perform better for slow subscribers even both schemes have less number of channels in comparison to TB scheme. According to Fig. 5 and Fig. 6 the call loss probability of CR and HDFS schemes is about same even the HDFS scheme has less channels; reserve as the guard channels for handling the handoff calls.

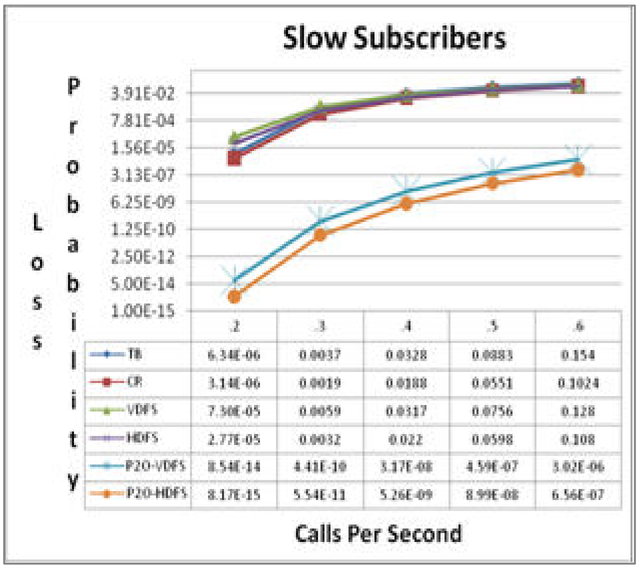

Figure 5(b): Comparison of numerical analysis on call loss probability with (.2 to.6) call arrival rate for slow subscribers

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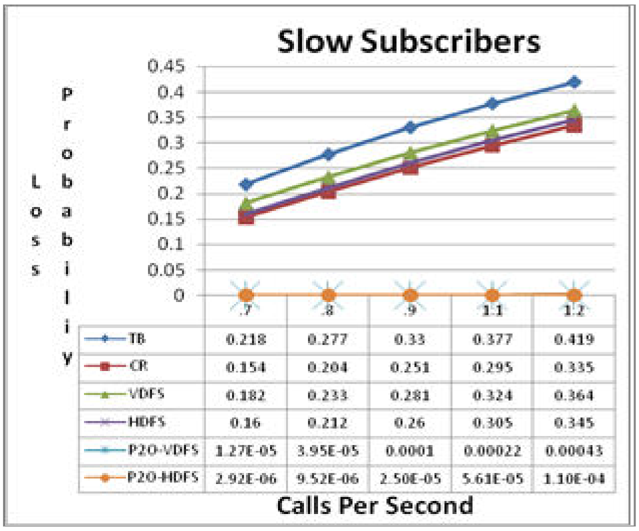
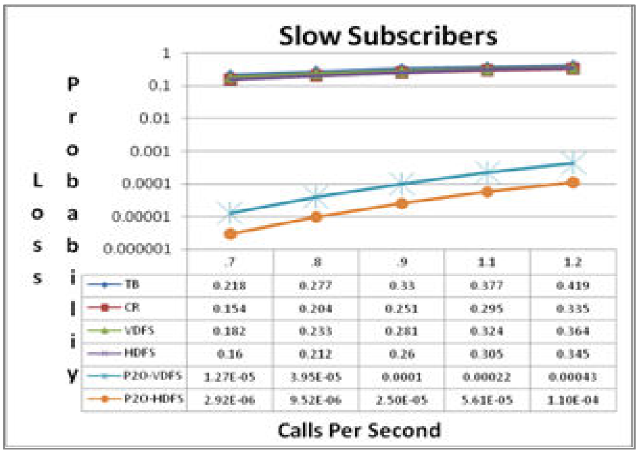


	.7	.8	.9	1.1	1.2
TB	0.218	0.277	0.33	0.377	0.419
CR	0.154	0.204	0.251	0.295	0.335
VDFS	0.182	0.233	0.281	0.324	0.364
HDFS	0.16	0.212	0.26	0.305	0.345
P2O-VDFS	1.27E-05	3.95E-05	0.0001	0.00022	0.00043
P2O-HDFS	2.92E-06	9.52E-06	2.50E-05	5.61E-05	1.10E-04

Figure 6(a): Comparison of numerical analysis on call loss probability with (.7 to1.1) call arrival rate for slow subscribers

We have seen that instantly increased slow speed visitors users stayed for few days, degrades the system performance by increasing network utilization, wireless interference, call blocking, and even call dropping from failed handoffs in TB and CR schemes due to non availability of guard channels. The proposed schemes are suggested to provide the services for slow speed visitor users in instantly high dense traffic area (hot spot). Microcells are used for providing the services to slow-speed, high-intensity traffic area users and macrocells are overlaid over more than one microcells cater mainly too lower density, high-speed users. Picocells are created that are underlaid to one microcell for handling the slow speed visitor (outside registered) users at hot spot area. It is observed that proposed schemes (in Fig. 5 and Fig. 6) perform better and therefore handle the traffic very efficiently in hot spot area. The visitor subscribers increased instantly for few days handled by P2cell in the proposed system, therefore macro-microcell network performs efficiently and call loss probability of entire proposed system is decreased.



	.7	.8	.9	1.1	1.2
TB	0.218	0.277	0.33	0.377	0.419
CR	0.154	0.204	0.251	0.295	0.335
VDFS	0.182	0.233	0.281	0.324	0.364
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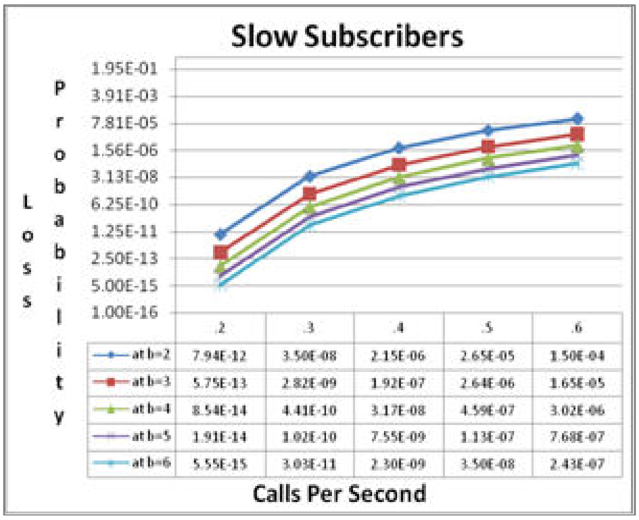
P2O-VDFS	1.27E-05	3.95E-05	0.0001	0.00022	0.00043
P2O-HDFS	2.92E-06	9.52E-06	2.50E-05	5.61E-05	1.10E-04

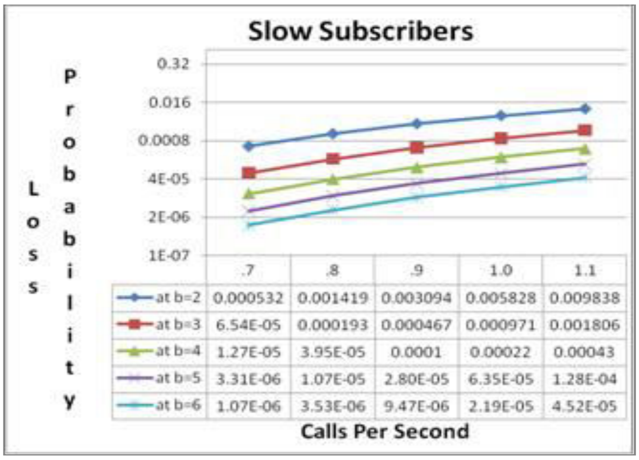
Figure 6(b): Comparison of numerical analysis on call loss probability with (.7 to1.1) call arrival rate for slow subscribers

Now, as soon as the total traffic rate is increased to the entire area as shown in Fig. 6 and the value of tune the strength of slow subscribers remains same i.e. q=0.7, then it is observed that the results for proposed schemes are too good (Fig. 6). P2O-HDFS scheme performs even better than P2O-VDFS scheme. In Fig. 6, we observed that TB, VDFS, HDFS and CR schemes perform about parallel to each others; therefore as soon as the traffic rate increases, the ability to improve the system performance of conventional schemes become same to each others. The call loss probability of the proposed schemes are, therefore, less than TB, VDFS, HDFS and CR schemes in the area where services to slow speed users in high intensity traffic area with instantly high dense traffic. In proposed system the picocells are portable, which installed on vehicle, therefore may be moved any time at the desired hot spot area.



	.2	.3	.4	.5	.6
at b=2	7.94E-12	3.50E-08	2.15E-06	2.65E-05	1.50E-04
at b=3	5.75E-13	2.82E-09	1.92E-07	2.64E-06	1.65E-05
at b=4	8.54E-14	4.41E-10	3.17E-08	4.59E-07	3.02E-06
at b=5	1.91E-14	1.02E-10	7.55E-09	1.13E-07	7.68E-07
at b=6	5.55E-15	3.03E-11	2.30E-09	3.50E-08	2.43E-07

Figure 7(a): Comparison of numerical analysis on call loss probability at different number of picocells per microcell with (.2 to.6) call arrival rate of slow subscribers for P2O-VDFS scheme



	.7	.8	.9	1.0	1.1
at b=2	0.000532	0.001419	0.003094	0.005828	0.009838
at b=3	6.54E-05	0.000193	0.000467	0.000971	0.001806
at b=4	1.27E-05	3.95E-05	0.0001	0.00022	0.00043
at b=5	3.31E-06	1.07E-05	2.80E-05	6.35E-05	1.28E-04
at b=6	1.07E-06	3.53E-06	9.47E-06	2.19E-05	4.52E-05

Figure 7(b): Comparison of numerical analysis on call loss probability at different number of picocells per microcell with (.7 to1.1) call arrival rate of slow subscribers for P2O-VDFS scheme

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We have also studied the effect of velocity of subscribers on loss probability. In Fig. 9, the doted and solid lines are represented to P2O-VDFS and P2O-HDFS schemes respectively. Marker options on different lines in Fig. 9 are the indicator of the different speed. In Fig. 9, we have found that slow speed subscribers relies more call loss probability in comparison to high speed of subscribers. Therefore speed and call loss probability are inversely proportional to each other. We have seen that pedestrian speed traffic performed less call loss probability instead of stayed or zero speed users. As soon as speed goes down of the subscribers, they feel high call loss probability in the hierarchical-tier cellular networks.

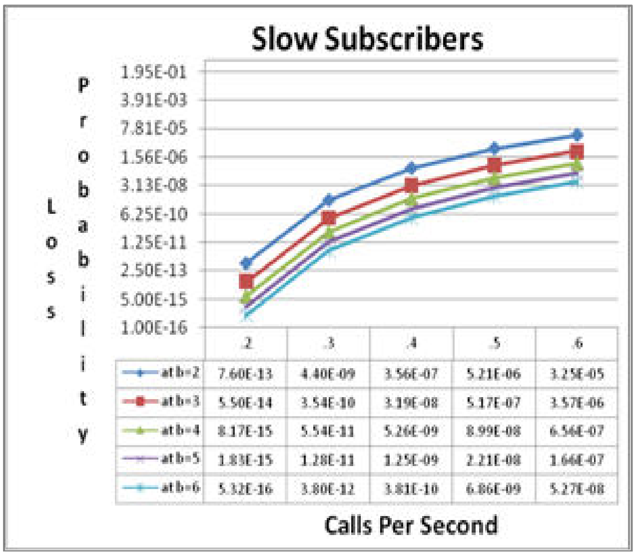


Figure 8(a): Comparison of numerical analysis on call loss probability at different number of picocells per microcell with (.2 to.6) call arrival rate of slow subscribers for P2O-HDFS scheme

We have also studied the effect of number of picocells to cover or service the hot spot, which has a fixed area. Therefore hot spot area that is serviced by the picocells is fixed. Here 'b' i.e. number of picocells per microcell are varied in our study to examine the loss probability metrics respond. The results are reported in Fig. 7 and Fig. 8. As per expectation, the loss probability is decreases in deployment of additional picocell, i.e. as the number of picocells 'b' per microcell increases, the loss probability decreases. We have seen initially that when calls rate in between .2 and .3 calls per second, decreasing rate of loss probability is lower than when calls rate in between .3 and .4 calls per second. But as soon as calls rate increases, the decreasing rate of loss probability goes down fast for both schemes P2O-VDFS (Fig. 7) and P2O-HDFS (Fig. 8).

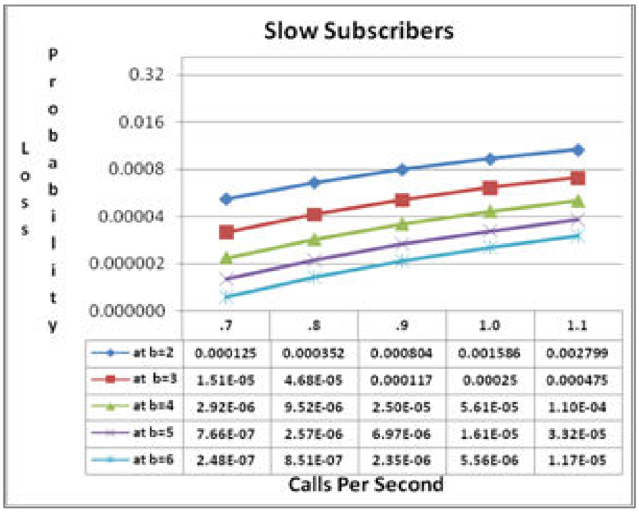


Figure 8(b): Comparison of numerical analysis on call loss probability at different number of picocells per microcell with (.7 to1.1) call arrival rate of slow subscribers for P2O-HDFS scheme

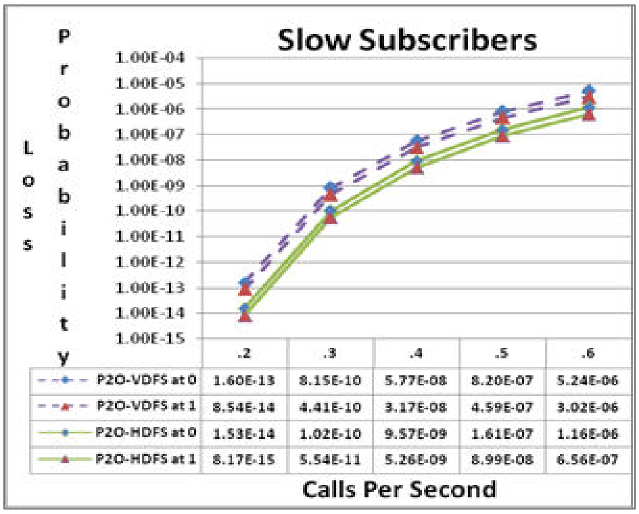
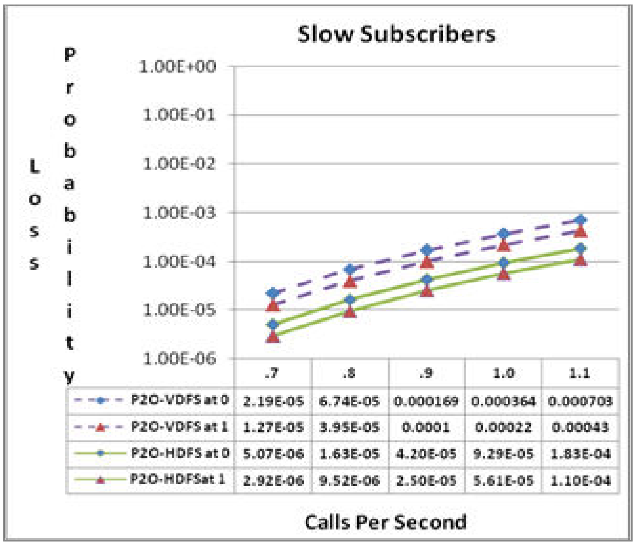


Figure 9(a): Comparison of numerical analysis on call loss probability at different speed with (.2 to.6) call arrival rate of slow subscribers for P2O-VDFS & P2O-HDFS schemes

The loss probability is less with higher number of picocells per microcell due to overflow mechanism that provides more alternative channel allocation facility. Compare the Fig. 7 and Fig. 8, we have seen that call loss probability in P2O-HDFS is more less in comparison to P2O-VDFS. As number of picocell increases per microcell, P2O-HDFS provides more horizontal direction sharing in picocell tier.



	.7	.8	.9	1.0	1.1
P2O-VDFS at 0	2.19E-05	6.74E-05	0.000169	0.000364	0.000703
P2O-VDFS at 1	1.27E-05	3.95E-05	0.0001	0.00022	0.00043
P2O-HDFS at 0	5.07E-06	1.63E-05	4.20E-05	9.29E-05	1.83E-04
P2O-HDFSat 1	2.92E-06	9.52E-06	2.50E-05	5.61E-05	1.10E-04

Figure 9(b): Comparison of numerical analysis on call loss probability at different speed with (.7 to1.1) call arrival rate of slow subscribers for P2O-VDFS & P2O-HDFS schemes

6. CONCLUSION

In this paper, P2O-VDFS, and P2O-HDFS schemes are proposed for hot spot area where slow or zero speed visitors subscribers are increased instantly for few days that degrades the system performance. The proposed schemes use Portable-Picocell that is underlaid to microcell to upgrade the system performance. An analytical model has been developed to derive some useful performance indices. The methods to improve the call loss probability in the service area that contains user population in sparse with slow, visitor and high speed users is proposed by taking the advantage of overlapping coverage of hierarchical-cellular system. It is also found that a significant reduction is obtained in call loss probability for proposed schemes. It is possible due to share the traffic load of visitor subscribers by P2cell in proposed schemes. P2O-HDFS scheme perform better than P2O-VDFS, because P2O-HDFS share the load horizontally in P2Ocell, if picocell fully occupied and not have any vacant channel to handle the new call request of visitor subscriber. The proposed schemes shows better performance in comparison to TB, CR, VDFS, and HDFS schemes for slow subscribers, even the total traffic rate is increased to entire area; value of tune the strength of the slow subscribers is increased. We have also seen that the call loss probability decreases with increasing the number of picocell in P2Ocell. We have further found that velocity also play vital role in call loss probability, which one inversely proportional to call loss probability as shown in Fig. 9.

Under the situation considered, we found by numerical results that the proposed traffic management scheme reduces call loss probability and enhances system performance. This observation agrees with other traffic management schemes with picocells.

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